## BMP: OUTLET PROTECTION

### Definition

Structurally lined aprons or other acceptable energy dissipating devices placed at the outlets of pipes or paved channel sections.

### Purpose

To prevent scour at stormwater outlets, to protect the outlet structure, and to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated stormwater flows.

### Conditions Where Practice Applies

Applicable to the outlets of all pipes and engineered channel sections.

### Planning Considerations

The outlets of pipes and structurally lined channels are points of critical erosion potential. Stormwater which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the capacity of the receiving channel or area to resist erosion. To prevent scour at stormwater outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

The most commonly used device for outlet protection is a structurally lined apron. These aprons are generally lined with riprap, grouted riprap or concrete. They are constructed at a zero grade for a distance which is related to the outlet flow rate and the tailwater level.

Where flow is excessive for the economical use of an apron, excavated stilling basins may be used.

<u>Design Criteria</u>

The design of structurally lined aprons at the outlets of pipes and paved channel sections applies to the immediate area or reach below the pipe or channel and does not apply to continuous rock linings of channels or streams (See STORMWATER CONVEYANCE CHANNEL, BMP-17). Notably, pipe or channel outlets at the top of cut slopes or on slopes steeper than 10% should not be protected using just outlet protection as a result of the reconcentration and large velocity of flow encountered as the flow leaves the structural apron. Outlet protection shall be designed according to the following criteria:

Pipe Outlets (See Figure 18-1)-

1.      Tailwater depth: The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a <u>Minimum Tailwater Condition.</u> If the tailwater depth is greater than half the pipe diameter, it shall be classified as a <u>Maximum Tailwater Condition.</u> Pipes which outlet onto flat areas with no defined channel may be assumed to have a <u>Minimum Tailwater Condition.</u>

2.      <u>Apron length:</u> The apron length shall be determined from the curves according to the tailwater condition:

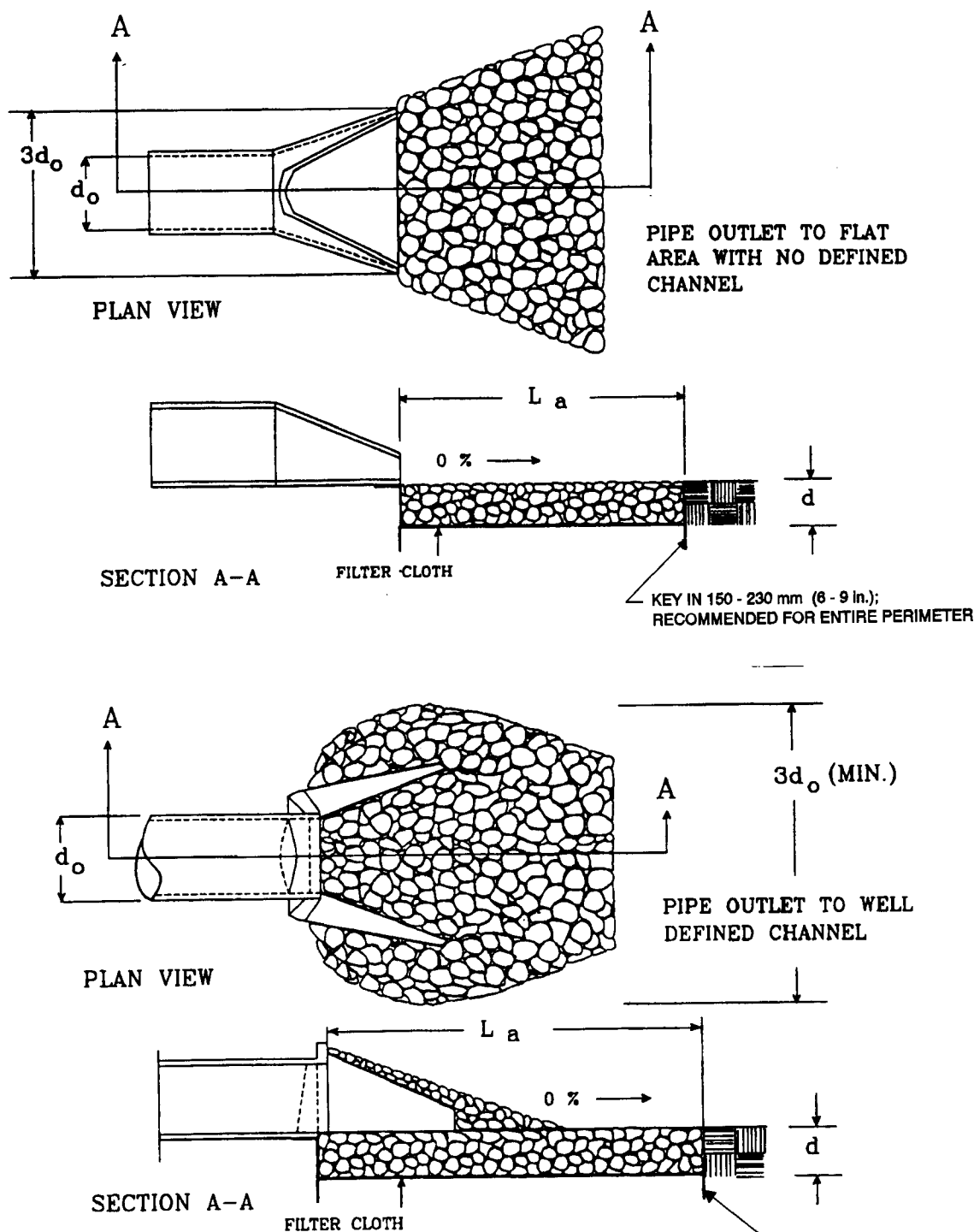> Minimum Tailwater - Use Figure 18-2
> Maximum Tailwater - Use Figure 18-3

3.      <u>Apron width:</u> When the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an elevation 0.3 meters (1 foot) above the maximum tailwater depth or to the top of the bank (whichever is less).

If the pipe discharges onto a flat area with no defined channel, the width of the apron shall be determined as follows:

a.      The upstream end of the apron, adjacent to the pipe, shall have a width three times the diameter of the outlet pipe.

b.      For a <u>Minimum Tailwater Condition,</u> the downstream end of the apron shall have a width equal to the pipe diameter plus the length of the apron.

# FIGURE 18-1: PIPE OUTLET CONDITIONS

$3d_o$

$d_o$

PLAN VIEW

PIPE OUTLET TO FLAT
AREA WITH NO DEFINED
CHANNEL

$L_a$

0 %

d

SECTION A-A

FILTER CLOTH

KEY IN 150 - 230 mm  (6 - 9 in.);
RECOMMENDED FOR ENTIRE PERIMETER

$d_o$

$3d_o$ (MIN.)

PIPE OUTLET TO WELL
DEFINED CHANNEL

PLAN VIEW

$L_a$

0 %

d

SECTION A-A

FILTER CLOTH

KEY IN 150 - 230 mm (6-9 in.);
RECOMMENDED FOR
ENTIRE PERIMETER.

NOTES:  1. APRON LINING MAY BE RIPRAP, GROUTED RIPRAP, GABION
            BASKET, OR CONCRETE.
        2. La IS THE LENGTH OF THE RIPRAP APRON AS CALCULATED
            USING PLATES 3.18-3 AND 3.18-4.
        3. d = 1.5 TIMES THE MAXIMUM STONE DIAMETER, BUT NOT
            LESS THAN 150 mm (6 in.).

C-99

# FIGURE 18-2

DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
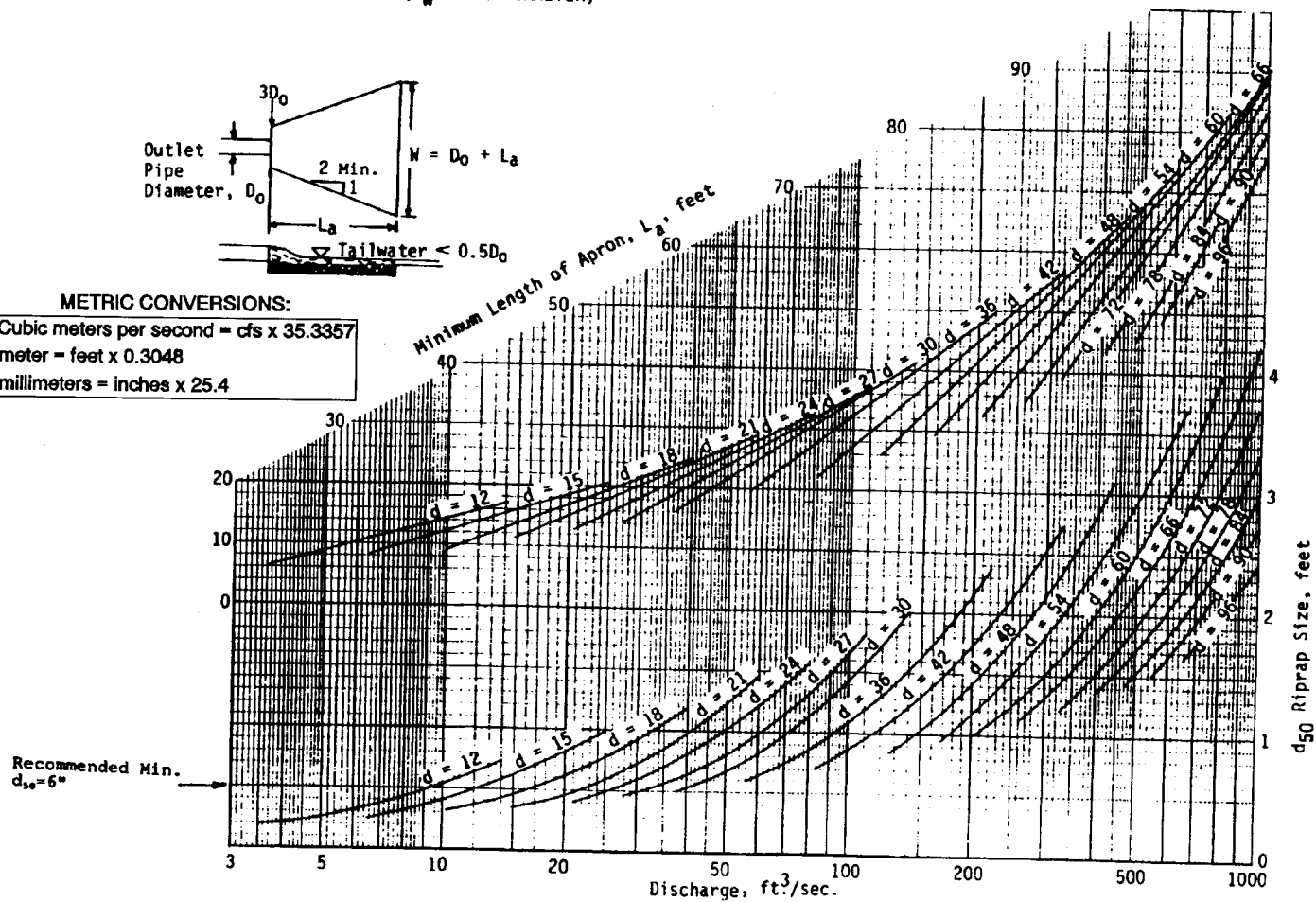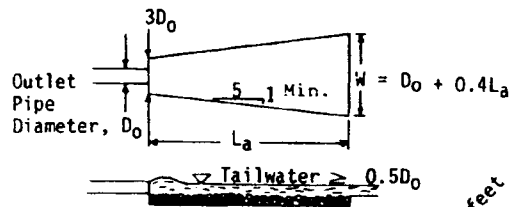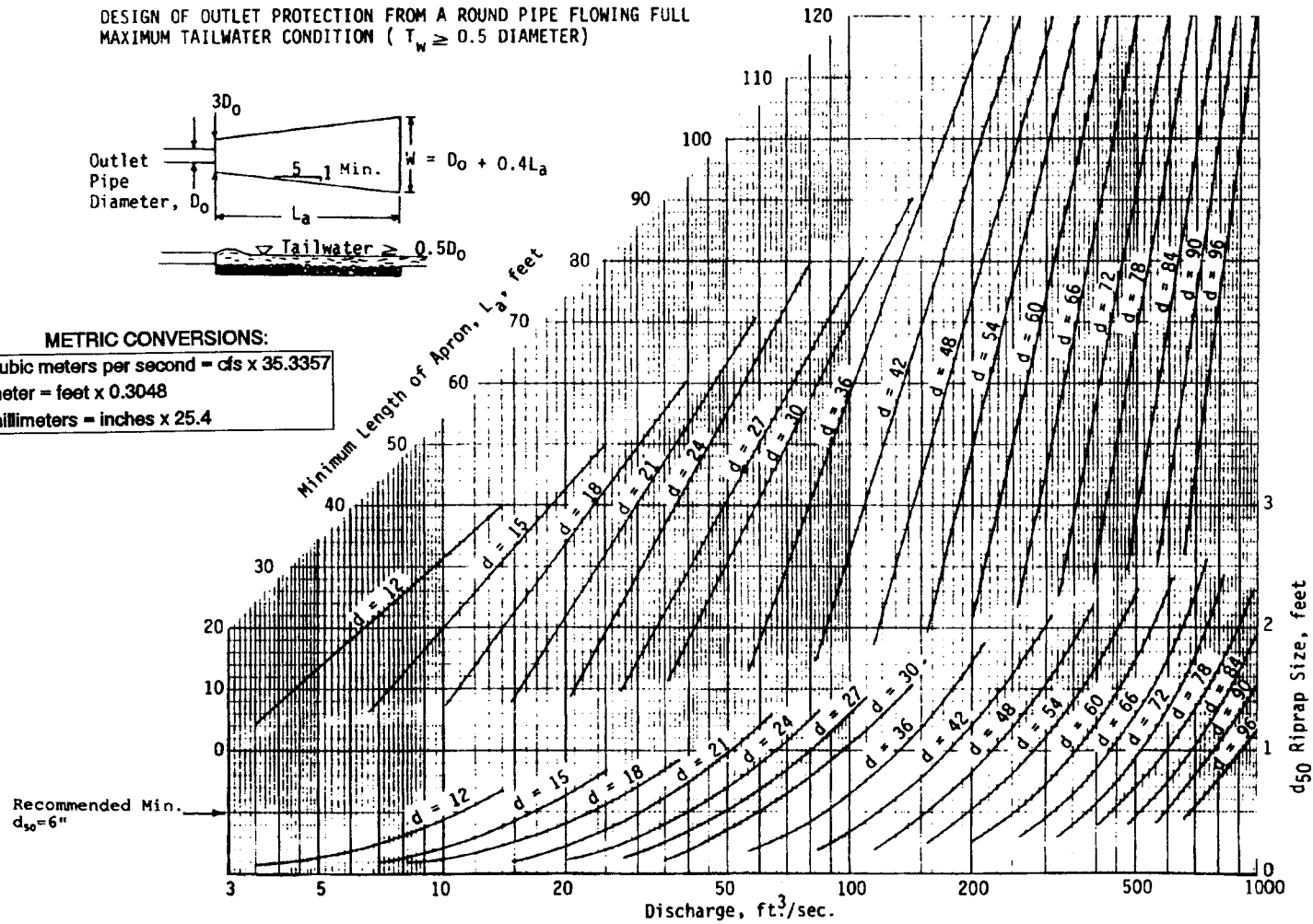MINIMUM TAILWATER CONDITION (T_w < 0.5 DIAMETER)

# FIGURE 18-3

DESIGN OF OUTLET PROTECTION FROM A ROUND PIPE FLOWING FULL
MAXIMUM TAILWATER CONDITION ( $T_w \geq 0.5$ DIAMETER)

METRIC CONVERSIONS:

Cubic meters per second = cfs x 35.3357

meter = feet x 0.3048

millimeters = inches x 25.4

Outlet Pipe Diameter, $D_o$

$3D_o$

$5\underline{\quad}1$ Min.

$W = D_o + 0.4L_a$

$L_a$

$\triangledown$ Tailwater $\geq 0.5D_o$

Minimum Length of Apron, $L_a$, feet

Recommended Min. $d_{50} = 6"$
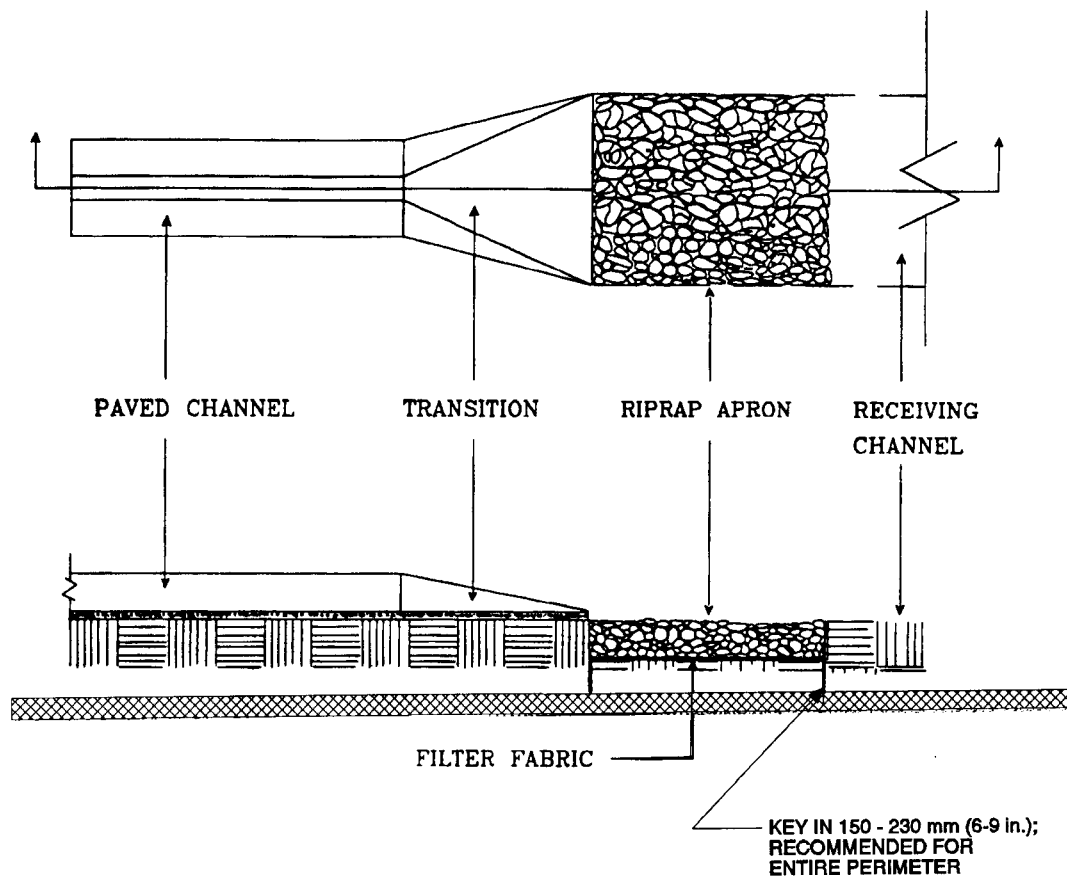
$d_{50}$ Riprap Size, feet

Discharge, ft³/sec.

c. For a <u>Maximum Tailwater Condition</u>, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron.

4. <u>Bottom grade:</u> The apron shall be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

5. <u>Side slopes:</u> If the pipe discharges into a well-defined channel, the side slopes of the channel shall not be steeper than 2:1 (horizontal: vertical).

6. <u>Alignment:</u> The apron shall be located so there are no bends in the horizontal alignment.

7. <u>Materials:</u> The apron may be lined with riprap, grouted riprap, concrete, or gabion baskets. The median sized stone for riprap shall be determined from the curves in Figures 18-3 and 18-4, according to the tailwater condition. The gradation, quality and placement of riprap shall conform to BMP-19, RIPRAP.

8. <u>Filter cloth:</u> In all cases, filter cloth shall be placed between the riprap and the underlying soil to prevent soil movement into and through the riprap. The material must meet or exceed the physical properties for filter cloth found in BMP-19, RIPRAP. See Figure 18-1 for orientation details.

Paved Channel Outlets (See Figure 18-4) -

1. The flow velocity at the outlet of paved channels flowing at design capacity must not exceed the permissible velocity of the receiving channel (see Tables 18-1 and 18-2).

# FIGURE 18-4: PAVED CHANNEL OUTLET

PAVED CHANNEL      TRANSITION      RIPRAP APRON      RECEIVING
CHANNEL

FILTER FABRIC

KEY IN 150 - 230 mm (6-9 in.);
RECOMMENDED FOR
ENTIRE PERIMETER

## NOTES:

1. RIPRAP APRON REDUCES THE FLOW VELOCITY BELOW THE
   PERMISSIBLE VELOCITY OF THE NATURAL RECEIVING CHANNEL.

2. TRANSITION SIDE DIVERGENCE IS 1 IN 3F, WHERE

$$F = \text{FROUDE NUMBER} = \frac{V}{\sqrt{gd}} \quad \text{WHERE}$$

V = VELOCITY AT THE BEGINING OF THE TRANSITION
d = DEPTH OF FLOW AT THE BEGINING OF THE TRANSITION
g = 9.82 m/sec² (32.2 ft/sec²)

2. The end of the paved channel shall merge smoothly with the receiving channel section. There shall be no overfall at the end of the paved section. Where the bottom width of the paved channel is narrower than the bottom width of the receiving channel, a transition section shall be provided. The maximum side divergence of the transition shall be 1 in 3F where;

$$F = \frac{V}{\sqrt{gd}}$$

where,

| | | |
|---|---|---|
| F | = | Froude number |
| V | = | Velocity at beginning of transition, meters/sec (feet/sec) |
| d | = | depth of flow at beginning of transition, meters (feet) |
| 9 | = | 9.82 meters/sec.$^2$ (32.2 feet/sec.$^2$) |

3. Bends or curves in the horizontal alignment at the transition are not allowed unless the Froude number (F) is 1.0 or less, or the section is specifically designed for turbulent flow.